8. STORMWATER MANAGEMENT PLAN

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Cardno
Engineering the Future

Nightcap Village, Uki

Stormwater Management Plan

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NIGHTCAP VILLAGE, UKI
STORMWATER MANAGEMENT PLAN

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1. INTRODUCTION

Peter Van Lieshout propose to develop a site on Kyogle Road in the Kunghur area of north-eastern New South Wales to create a residential village. The site falls within the jurisdiction of Tweed Shire Council, and as the site is adjacent to the Tweed River, an assessment is required to ensure that the development has no adverse effects on the Tweed River in terms of runoff quantity or quality. This report details Cardno's advice in this regard.

The site, of over 45 hectares in area, is currently characterised by pockets of woodland among open grassland. Development proposals include residential lots of varying density, with accompanying recreational and commercial areas. An increase in impermeable area and human activity across the site has the potential to increase both the rate of runoff, and the pollutants entrained within it. To overcome this, a conceptual treatment train has been developed that encompasses water sensitive urban design principles.

The proposed development will be constructed in three stages, each being 'self sufficient' in terms of runoff quantity and quality. All stages will include rainwater tanks for roof areas, buffer strips to treat lot drainage, infiltration trenches to deal with road runoff, and proprietary gross pollutant traps to remove litter and debris. All runoff from events of up to the three-month return period will finally filter through bioretention basins before release to the watercourse, providing a high quality discharge with no detriment to the receiving waters.

Stormwater detention measures will be employed to ensure that there is no overall increase in the rate of runoff from the site, avoiding flooding problems downstream. Existing dams will be utilised to store stormwater for controlled release, and new facilities will be constructed as appropriate (often being combined with the bioretention systems described above).

The proposed site and its treatment systems have been modelled using MUSIC 3.01. It demonstrates that development can proceed without producing an increase in the total annual export of pollutants from the site when compared to the existing situation. Further, the proposed system will meet accepted efficiency standards for the removal of key pollutants.

For the analysis, stormwater quantity issues were considered in accordance with the requirements of Tweed Shire Council Development Control Plan 16, and quality issues considered in accordance with Development Design Specification D7. The final type, capacity and dimensions of the devices will be subject to detailed design at a later stage.

2. STORMWATER QUANTITY

2.1 Methodology

Peak discharges were calculated using the Rational Method, in accordance with *Australian Rainfall and Runoff* (Institute of Engineers Australia, 1987), after having established the areas of each zone. Design rainfall intensities were calculated with AUS-IFD software, using the parameters set out in Table 1.

Table 1 Rainfall Parameters for

Log Normal Intensities				Geographical factors	
2 year ARI		50 year ARI			
1 hr	47.5	1 hr	88	Skewness G	0.075
12 hr	11.9	12 hr	25	F2	4.4
72 hr	4	72 hr	9.5	F50	17

The primary design aim is to ensure that runoff rates downstream of the site do not increase following development, both to prevent scour in existing watercourses and to prevent possible flooding problems. This is achieved by providing a storage area that detains the increased runoff flow, releasing it in a controlled manner at a rate that resembles the situation prior to development.

2.2 Management of Stormwater Runoff

The Rational Method was used to determine the peak 100-year event discharge in both the existing and developed cases.

This study analyses the entire site using the three construction stages proposed by the developer. The first of these, to the northwest of the site, features areas of low and medium density residential development, and includes the majority of the 'mixed village' zone, which will include commercial areas. The stage also features a recreational area and two waterbodies. As well as providing an aesthetic and recreational asset for the development, the waterbodies will be used for stormwater attenuation.

The second area, to the northeast of the site, also features low and medium density residential development. This stage also includes a large sports pavilion and several carparking areas. The majority of the stage is below the level of the aforementioned waterbodies and will therefore require dedicated attenuation measures.

Lastly, the third southern stage features more medium density housing, and the remainder of the mixed village zone. This stage includes the River Tweed itself, as it flows from the west to east through the site. The lowest of the stages, attenuation devices will also be required, set above the 100-year flood level of the River Tweed.

2.2.1 Impervious areas

The whole site is assumed to be completely pervious in its current state. Time of concentration has been estimated using Friend's equation, and taken to be 30 minutes for all of the stages.

Following development, the site will be impervious to differing degrees. The calculations and modelling have allowed for this and each development type is assessed separately. At this preliminary stage, pervious fractions have been estimated for each development type as set out in the table below.

Table 2 Development Type and Impervious Fractions

Development Type	Estimated Impervious fraction
Residential	0.5
Village Residential	0.7
Mixed Village	0.8
Health Facilities	0.9
Open Space	0
Roads	1
Parking	1
Rehabilitation	0

Where the development zones have impervious fractions that are not zero, the time of concentration has been taken as 5 minutes.

For all the stages, the remainder of the area (not subject to development, and classified as General Open Space) has not been included in the calculations. Existing runoff rates from these areas will not be affected following development, and provision has not therefore been made for treatment or attenuation.

Table 3 provides a summary of these calculations. The calculations are conservative by nature, given that impervious areas have been overestimated, and that rainwater tanks have not been accounted for.

The table includes the detention volume required to successfully mitigate against increases in the rate of runoff.

2.3 Existing and Developed Case Results

Any increase in impervious area following development could result in an increase in the rate of stormwater runoff, and the detention of peak storm flows is therefore required to ensure hydraulic conditions downstream of the proposed site remain as similar to the existing situation as possible.

The detention parameters required for the catchment are outlined in Table 2. The preliminary sizing of the detention basin was carried out according to the methodology outlined in QUDM (refer Section 6.06.1, QUDM). As a conservative approach, the required detention volume was determined by adopting the largest volume derived from each of the formulae discussed in QUDM.

Table 3 Rational Method Results Summary

Stage	Peak Flow Q_{100} (m^3/s)		Detention Requirement		
	Existing Case	Developed Case	Volume (m^3)	Approx Surface Area (m^2)	Assumed Depth (m)
1	3.94	7.77	3050	7750	0.42
2	1.79	3.41	2600	3250	1
3	2.35	4.57	3550	4320	1

The waterbodies located in Stage 1 have an area of approximately 7750m^2 in total. If used to attenuate stormwater during the 100-year event, standing water levels in the ponds would rise by just over 400mm.

Stages 2 and 3 would require dedicated detention basins of the dimensions shown, as they lie below the level of the waterbody contained within Stage 1. The detention volume quoted features a factor of safety of two to account for side slopes and other losses. This does not apply for the waterbodies described above, as they are existing features and only the increase in depth is of interest.

It is expected that a more rigorous assessment of detention dimensions and associated conveyance routes will be carried out during detailed design to confirm that no increase in peak discharge from the site occurs for all events up to and including the 100 year event.

3. STORMWATER QUALITY

3.1 Stormwater Management Practices

A wide range of stormwater management practices is available to achieve the principles of Water Sensitive Urban Design. All have been shown to be successful when correctly designed, but selection of the most appropriate practices for a particular development is highly dependent on site conditions.

Table 4 lists the most common stormwater management practices currently used, along with opportunities and constraints for their use. This table forms the starting point for stormwater management for the site. Considering the site's constraints, not all of the measures outlined in Table 4 are suitable. Each treatment option is therefore discussed in more detail and comment made on the suitability of each in the context of the development.

Table 4 **Stormwater Management Practices**

Practice	Opportunities			Constraints
	Pollutants removed	**Scale**	**Other**	
Litter baskets/racks	Litter and debris – M	Local	Pre-treatment for other practices	Require frequent maintenance
Sediment traps	Coarse sediment – H Suspended solids – L	Regional		Aesthetic and safety issues
Gross pollutant traps (GPTs)	Litter and debris – M Coarse sediment – H Suspended solids – L	Regional	Pre treatment for other practices	Require regular maintenance
Filter strips/ buffer strips	Litter and debris – M Coarse sediment – H Suspended solids – H Nutrients – M	Lot/Local	Peak flow management	Require flat terrain
Grass swales	Litter and debris – M Coarse sediment – H Suspended solids – H Nutrients – M	Local	Peak flow management	Require flat terrain
Vegetated swales	Litter and debris – M Coarse sediment – H Suspended solids – H Nutrients – H	Local	Peak flow management	Require flat terrain
Extended detention basins	Coarse sediment – M Suspended solids – M Nutrients – L	Regional	Peak flow management	Requires pre-treatment Large land area required
Infiltration trenches	Suspended solids – H Nutrients – M	Local	Peak flow management	Requires pre-treatment
Bioretention systems (rain garden)	Coarse sediment – H Suspended solids – H Nutrients – H	Local	Peak flow management	Requires pre-treatment
Porous pavements	Suspended solids – H Total phosphorus – M Total nitrogen – L	Local	Peak flow management	Not appropriate for steep sites
Constructed wetlands	Coarse sediment – H Suspended solids – H Total phosphorus – M Total nitrogen – L	Regional	Peak flow management	Requires pre-treatment Not appropriate for steep sites Requires large area of land
Rainwater tanks	N/A	Lot	Peak flow management	Requires community involvement
Community education	Litter and debris – L Nutrients – L	Regional	Other benefits include weed control, reduced water use	Community participation

Note Data taken from NSW EPA Managing Urban Stormwater – Treatment Techniques, 1997
L – 10 - 50% removal
M – 50 – 75% removal
H – 75 - 100% removal
Scales Lot less than 1 ha
Local 1 – 10 ha
Regional greater than 10 ha

3.2 Outline Suitability Assessment

Each of the techniques described is Table 4 is further assessed below, with regard to the site's specific opportunities and constraints.

Litter Baskets/racks

The primary purpose for litter baskets is to remove medium sized litter and debris from the site. Significant litter loads are not expected and other measures will be more appropriate for managing the removal of litter from the site.

Sediment Traps

Sediment traps will be required during the construction phase to limit the transport of sediment off site. Following construction, sediment levels will return to a low level, and traps are therefore not considered necessary as a long-term water quality measure.

Gross Pollutant Traps

Gross pollutant traps (GPTs) are predominantly used for the removal of litter and debris – although they have been shown to effectively remove coarse sediment and suspended solids (Brisbane City Council, 1999). GPTs will be placed before bioretention basins to reduce pollutant loads and prolong filter life.

Filter Strips/Buffer Strips

Buffer strips are areas of land left in their natural state that act to reduce peak runoff flows and improve the quality of stormwater runoff. Buffer strips are considered to be a valuable component of the stormwater management system for this development. This treatment improves the aesthetic and biodiversity value of the development and provides significant quality and quantity improvements.

Grass Swales

Grass swales are considered a highly effective and aesthetic water quality (and to a lesser extent, water quantity) control measure, when placed in flat areas. In this case, vegetated swales, described below, are more appropriate.

Vegetated Swales

Vegetated swales require similar conditions as those outlined for grass swales above. Space is limited in the commercial development, but car park dividing features and edges could be utilised, both for aesthetic purposes and to serve a water quality function. The road areas will be drained towards them, and they will incorporate a filter bed and conveyance system. Their usefulness increases when combined with a filter (see 'Bioretention Systems').

Extended Detention Basin

Extended detention basins are designed to generally store runoff for 1-2 days. Their main purpose is the reduction of the peak discharge from the site during a storm event, and the retention of particulate matter.

Infiltration Trenches

Infiltration trenches allow pre-treated stormwater runoff to infiltrate to into surrounding soils and groundwater, and as such are not a treatment device in themselves. Where space is limited, bioretention systems are preferred.

Bioretention Systems

Bioretention systems effectively combine a grass or vegetated swale with an infiltration trench. They are considered to be extremely effective in removing sediment and nutrients. Although they require a flat area, they can be incorporated in steeper areas using a stepped system. They can also be located within a detention basin, thereby combining the stormwater quality and quantity functions into a smaller area. Bioretention systems are considered appropriate for all development stages. Bioretention processes will also occur in the filters installed beneath the swales serving the road areas.

Porous Pavements

Porous pavements are not appropriate for high traffic areas due to increased maintenance requirements. They are also less effective in steep areas.

Constructed Wetlands

Wetlands require reasonably large flat areas of land. Such an area exists in Stage 1. This will be utilised as an attenuation facility, but flows will be treated to a suitable degree before entry to the waterbody to prevent litter nuisance, nutrient build-up and possible eutrophication.

Rainwater Tanks

The ability exists to install rainwater tanks throughout the development to reduce overall water consumption, and where space permits tanks with significant storage volumes could be utilised.

Tanks are an extremely useful aid to water conservation, and also have some effect in reducing nitrogen levels. The capacity of the tanks has been discounted in stormwater runoff calculations however, as although they can have a considerable effect in reducing runoff volumes, they cannot be assumed to be empty when needed.

3.3 Proposed Stormwater Management

In summary, the stormwater management practices considered appropriate for use in this development are:

- gross pollutant traps on roadways and to intercept flows to bioretention basins;
- vegetated swales to collect runoff from roads, incorporating bioretention systems in their base for the removal of sediment and attached nutrients;
- rainwater tanks for the collection and reuse of roof runoff;
- buffer strips to intercept impervious areas on residential lots;
- infiltration systems for the Village Green and Oval;
- bioretention basins for all stages; and,
- existing waterbodies in Stage 1 for final polishing (also serving as attenuation devices).

To ensure that the Water Quality Objectives (described in the following section) can be met, devices will be sized such that all stormwater up to the three-month design flow will have passed through the nominated measures for treatment.

4. WATER QUALITY MODELLING

4.1 Site Specific Objectives

Water Quality Objectives (WQO) for the study site have been derived from the *Tweed Urban Stormwater Quality Management Plan*. Council has developed interim water quality objectives following the advice given in the ANZECC Water Quality Guidelines for Fresh and Marine Waters (1992), and an assessment of similar watercourses in the region. These interim water quality objectives, adopted by Council in 1998, are presented in Table 5 below.

Table 5 Tweed Shire Council Interim Water Quality Objectives

Parameter	Units	Freshwater segments
PH	pH units	6.5-9
Dissolved Oxygen	mg/L	>6
Suspended Solids	mg/L	<20
Total Phosphorus	mg/L	<0.10
Total Nitrogen	mg/L	<0.75
Chlorophyll a	mg/L	<10
Faecal Coliforms	No./100mL	<150

Tweed Shire Council recognises that background water quality levels are difficult to assess due to natural variations in aquatic systems, and also that the guideline concentrations relate to in-stream values rather than the quality of water discharged from land.

In order to overcome this, Council has developed further objectives for the Post Construction or Occupational Phase of Development. Using a mix of water sensitive subdivision and development project design, source controls and end of pipe solutions, the following objectives should be achieved in the long term:

Table 6 Stormwater Treatment Objectives for Post Construction Phase of Development

Pollutant	Average Year (1719mm)	Wet Year (2185m)	Dry Year (929mm)
	Maximum permissible load, kg/ha/year		
Suspended Solids	300	400	120
Total Phosphorus	0.8	1.1	0.35
Total Nitrogen	4.5	6	1.5
Litter	Retention of 70% of annual load greater than 5mm		
Coarse Sediment	Retention of 90% of annual load of sediment coarser than 0.125mm		
Oil and Grease	<10mg/litre in flows up to 40% of Q1 peak		

Of all the above parameters, only the detailed modeling of suspended solids and nutrients (nitrogen and phosphorus) is possible at present using the industry standard analysis package (MUSIC), due to the lack of information regarding export rates. The modelling of defined water quality objectives has therefore necessarily focused on these parameters. For the remaining water quality indicators, it is necessary to consider the likely efficiency of the proposed treatment measures.

Based on the average removal efficiencies predicted in Table C4.3 of the Brisbane City Council *Water Quality Management Guidelines* (2000), the likely removal efficiency of the proposed treatment measures is as follows:

- Litter 83 percent removal
- Heavy Metals 77 percent removal

These rates of removal will be sufficient to provide an appropriate level of treatment to runoff. With respect to faecal coliforms, it is expected that the exposure to sunlight and filtration afforded by the bioretention systems will provide a sufficient reduction in faecal coliform concentrations.

With respect to dissolved oxygen, it is expected that runoff will not contain significant concentrations of oxygen demanding substances. In any case, the drainage of the majority of runoff from the site will take the form of slow release from the base of the infiltration areas to be used for the bioretention systems. The discharge of the slow flow will allow ample opportunity for aeration.

As well as achieving the maximum permissible loads set out in Table 6, the development will be designed in accordance with the guidance set out in Tweed Shire Council's *Development Design Specification D7: Stormwater Quality* (particularly at the detailed design stage, when sizing constructed wetlands, for example). In addition, two alternative and accepted benchmarks have been examined and expressed in this report. The first is to ensure that the overall annual pollutant load is not increased following development. The second is to ensure that minimum treatment train efficiencies are achieved. The results of these three tests are presented in the following sections.

4.2 MUSIC Methodology

In order to determine the effectiveness of the proposed treatment train in meeting these water quality objectives, a stormwater quality analysis was performed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 3.01. The model requires the user to specify meteorological data (rainfall and evaporation), soil properties and pollutant loads for each catchment, and suitable parameters for the MUSIC model were adopted in accordance with the recommendations of Tweed Shire Council's *Development Design Specification D7: Stormwater Quality* (v1.3, August 2005).

Tweed Shire Council has defined source nodes for urban, rural and undeveloped land use types. Based on these, the existing situation was modelled as 'Rural Tweed' as opposed to 'Undeveloped', as the area has been subject to clearing and grazing. For the proposed development, the three stages were further broken down into individual land use types according to the developer's structure plan (such as residential, mixed village, open space etc). Most were modelled using the 'Developed Tweed' source node, with the exception of Open Space and areas set aside for rehabilitation, which were modelled as 'Rural Tweed'.

Specification D7 gives the percentage impervious area that should be used with each source node. However, these apply when adopting an overall view of a development, but in this case the stages and the development zones within them have been more closely analysed.

Table 2 described the impervious fractions for each development type. However, these applied for runoff calculations, and a refinement was required for the quality modelling process. In order to accurately asses the effects of source controls such as rainwater tanks and buffer strips, it is necessary to separate out roof and lot area within each development type, as is shown in Table 7.

Table 7 Development Type and Impervious Fractions for Quality Modelling

Development Type	Overall Impervious fraction	'roof' fraction, 100% impervious	'lot' fraction, 25% impervious
Residential	0.5	0.33	0.66
Village Residential	0.7	0.5	0.5
Mixed Village	0.8	0.75	0.25
Health Facilities	0.9	0.8	0.2

'Roof' fractions are consistently lower than the overall impervious fractions, because the 'lot' area will also contain impervious areas such as paths, patios and driveways. Each of the above development types was therefore modelled using two nodes: the first being completely impervious and discharging to rainwater tanks of appropriate total size, and the second being 75% pervious and discharging over buffer strips. It can be seen that the new combined impervious fractions are slightly lower than those used in the runoff calculations, providing a conservative assessment of detention requirements.

The three source nodes were downloaded from Council's website, together with the 6-minute rainfall data series for Murwillumbah for 1978 (with a rainfall total of 1693mm, this can be regarded as an 'average' year). Flow-based sub-samples were used to exclude periods of dry flow (<0.1L/s), resulting in modified, more realistic, median results. The runoff generation parameters adopted are listed in Appendix B, together with the pollutant export relationships.

4.3 Conceptual Treatment Train

The site has been divided into three stages, in accordance with the planned development of the site over time. The stages are largely similar in their area and content, and so it is more convenient to describe the proposed treatment measures that have been adopted for each source type:

Residential, Village Residential and Mixed Village Zones:

Roof and lot areas have been regarded separately as described in the previous section. Rainwater tanks are used to intercept the high-quality runoff from roofed areas. Lot areas, or 'green' areas in the case of the Mixed Village zone, are regarded as being 25% impervious. Runoff from these areas is routed through buffer strips.

All runoff from developed areas of the site is then conveyed along shallow vegetated swales to a bioretention basin, protected by an upstream gross pollutant trap (GPT).

Roads and Car Parking Areas

Where the treatment train as a whole is seen to be meeting its objectives, runoff from roads and parking is routed direct to the GPT and onto the bioretention basin. Where particularly large areas of roads or parking are involved, or the system is already stressed, then after passing through dedicated in-situ GPTs, bioretention swales will be employed.

These have been modelled as 100m or 200m long vegetated swales (as necessary) of up to 5m wide, but featuring a sandy loam filter medium of one metre depth beneath. This filter trench could be lined as necessary to protect groundwater quality, and seepage losses have not been included at this stage.

All runoff deriving from roads and car parks is then directed through the bioretention basin, regardless of pre-treatment.

Open spaces

Although assumed to be completely pervious, any runoff that does originate from the landscaped open spaces around the site could be contaminated with fertilisers and such like, and would therefore require treatment. A system has been modelled for each that takes the form of a vegetated margin around the perimeter of the landscaped area, specifically designed to allow infiltration of runoff into the subsoil. The margin would be up to two metres wide and half a metre deep, and if conditions are not already favourable, it would include a subsoil media to allow infiltration at a rate of 36mm/hr.

Runoff from open spaces is routed in the model to the receiving node, and undergoes no further treatment.

Areas for set aside for rehabilitation have been included in the model, but are not subject to water quality treatment measures. Efforts will be made to return these areas to their natural state, and the conservation management measures employed will preclude the use of fertilisers and such like.

4.4 Device Sizing

Rainwater Tanks

Total tank sizes are entered for each development zone, assuming each dwelling utilises a 2400 litre capacity tank. To establish the number of dwellings, Residential zones were divided by an anticipated lot size of 600m^2, Village Residential zones by 400m^2 and Mixed Village zones by 200m^2.

Buffer Strips

Each buffer strip was assumed to treat all of the impervious area it serves, and occupy an area equivalent to 5% of the buffered area. A seepage loss of 36mm/hr has been assumed.

Vegetated Swales

The exact dimensions and capacity of the conveyance channels will be determined at the detailed design stage. For the moment, they have been assumed to be 0.75m deep and approximately 10m wide at their widest and 2m at their base.

Gross Pollutant Traps

Standard practice is to size GPTs to treat runoff from the 3-month event, which is taken to have a magnitude equal to 40% of the one-year event. As part of the detailed design, gross pollutant traps (such as Ecosol or Humeceptor units) will be sized for the site. The traps have been modelled as removing 40 percent of suspended solids, and 20 percent of the phosphorus and nitrogen loads, in accordance with Brisbane City Council guidelines (2000).

Bioretention Devices

As noted in Section 3.2, bioretention devices consist of a vegetated storage area over a filter media. Ponding in the vegetated storage area allows the settlement of sediment and the uptake of nutrients. Sediment and nutrient removal is enhanced by the stored runoff draining through a filter media in the base of the storage area.

It is desirable to limit the rate at which water drains from the system to maximise performance. For this reason, the plan area of the filter media is typically less than the surface area of the storage.

The following parameters have been adopted:

Table 8 Bioretention Device Parameters

Parameter	*1*	*2*	*3*
Surface Area (m^2)	7500	3500	4800
Filter Area (m^2)	1000	200	250
Extended Detention Depth (m)	1	1	1
Seepage Loss (mm/hr)	0	0	0
Filter depth (m)	0.5	0.5	0.5
Filter type	Sandy loam	Sandy loam	Sandy loam
Filter median particle diameter (mm)	0.45	0.45	0.45
Saturated hydraulic conductivity (mm/hr)	180	180	180
Depth below underdrain pipe (%)	0	0	0
Overflow weir (m)	2	2	2

In order for the bioretention system to work effectively, it must be installed correctly and properly maintained. If installed correctly, maintenance of the system will be minimal and infrequent.

The planting soil shall be a uniform mix, free from large objects (greater than 50mm in diameter). No materials which may be harmful to plant growth shall be mixed with the soil within the infiltration trench. The infiltration trench soil shall be free of all declared plants as specified under the Rural Lands Protection Act (1985).

Planting within the bioretention trench area shall consist of Lomandra Longifolia (long stemmed matrush) or Lomandra Hystrix (Matrush) planted at a spacing of 1 metre between stems. The area outside the bioretention trench (and within the bioretention area) can be grassed or provided with an alternate landscape treatment.

4.5 Modelling Results

A MUSIC model was developed that first examined the existing situation, as nutrients would be expected in runoff deriving from undeveloped areas. A simulation was then made of the effect of the proposed development, but without Water Sensitive Urban Design techniques. Finally, the performance of the sustainable drainage systems described in the previous section was assessed.

The results produced by the model are reported in Table 9 below.

Table 9 Total Annual Loads, Existing and Proposed

Zone	Total Suspended Solids (kg/yr)		Total Phosphorus (kg/yr)		Total Nitrogen (kg/yr)	
	existing	proposed	existing	Proposed	existing	Proposed
1	5410	763	13 5	7 64	81.0	71.4
2	2750	454	7.08	3.29	42.6	37
3	5280	1020	13.8	4.98	83.7	53.0
Total	**13440**	**2237**	**34.38**	**15.91**	**207.3**	**161.4**

As would be expected, development has the potential to increase suspended solids and nutrient levels in runoff from the site. However, it can be seen that the application of the proposed drainage designs would reduce all of the total loads released from the developed site compared to the existing.

In accordance with Tweed Shire Council's objectives, the above total values have been examined in terms of developed area, to give amounts in kilograms per hectare per year. Table 10 below shows the results compared to the maximum permissible loads that may be discharged.

Table 10 Pollutant Loads per Hectare per Year

Zone	Stage area (hectares, not including general open space)	Total Suspended Solids (kg/ha/yr)	Total Phosphorus (kg/ha/yr)	Total Nitrogen (kg/ha/yr)
1	12.6	60.6	0.47	5 67
2	5.73	79.2	0.57	6.45
3	7.53	135	0 66	7.04
Target		**300**	**0.8**	**4.5**

It can be seen that in all cases for suspended solids and phosphorus, the discharges from the site are lower than the permissible values, and for nitrogen the values are of a similar order. However, the site includes areas classified as General Open Space, and as these will be left largely in their original state, have not been included in the modelling in accordance with the conservative approach.

If included, the total Stage areas increase to 16.3, 8.5 and 16.8 hectares respectively. This is a better indication of the low overall density of the development, and reduces the total pollutant loads per hectare per year by around one third.

Finally, the performance of the treatment train can also be assessed by examining its removal efficiency. Brisbane City Council, for example, has set removal efficiency

targets, and it can be seen from Table 11 below that these have been achieved in all cases.

Table 11 MUSIC Removal Efficiencies (%)

	Suspended Solids	Total Phosphorus	Total Nitrogen
1	95.3	85.2	70.6
2	93.0	79.1	61.9
3	88.8	78.0	61.2
SITE TOTAL (area weighted)	92.9	81.8	65.9
Target	80	60	45

4.6 Construction Phase Sediment Control

During the construction phase, the potential exists for significant increases in the amount of pollutants, particularly sediment, exported from the site. During this period, an Erosion and Sediment Control Plan is required as part of the overall Environmental Management Plan prepared for the construction phase.

The erosion and sediment control plan for the site would be completed in accordance with *Soil Erosion and Sediment Control, Engineering Guidelines for Queensland Construction Sites* (Institution of Engineers Australia, 1996). The completion of construction activities in accordance with the above guidelines will minimise the nature of any adverse impacts during the construction phase.

It is considered that the appropriate time for the preparation of the Erosion and Sediment Control Plan is at the Operational works stage. Further, it is expected that the requirement to prepare a plan will be a condition of any development approval issued with respect to the site.

The performance criteria applicable to the development during the construction phase are listed in Tweed Shire Council's Urban Stormwater Quality Management plan, as follows:

- Minimise soil erosion and exposure
- Minimise transportation of eroded soil by air and water
- Limit suspended solids concentration in stormwater to not more than 50mg/L
- Limit/minimise the amount of site disturbance
- Isolate the site by diverting clean upstream 'run on' water around the development
- Control runoff and sediment at its point source rather than at final point
- Stage ground disturbance/earthworks and progressively revegetate the site where possible to reduce the area contributing sediment
- Retain topsoil for revegetation works
- Locate sediment control structures where they are most effective and efficient

These objectives will be achieved in accordance with '*Tweed Shire Council, Aus Spec D7 – Stormwater Quality* and Annexure A – Code of Practice for Soil and Water

Management on Construction Works'. Should there be non-compliance with the performance indicators prepared as part of the overall EMP for the construction phase, the following corrective actions are to be implemented.

- Identification of the cause of the non-compliance;
- Implementation of appropriate mitigation measures as determined by the Contractor in consultation with the Consultant; and
- Relevant validation monitoring to confirm that the nominated corrective actions have been effective.

It is envisaged that the bioretention systems will first be constructed as sediment basins to treat runoff during the construction phase. At the end of construction, the basins would have any accumulated sediment removed and the bioretention filter and vegetation installed. As there is likely to be a significant sediment load generated as houses are built on lots following the completion of subdivision works, it may be necessary to replace the filter media at intervals until the catchment is fully established.

4.7 Ongoing Maintenance

The proposed maintenance for the bioretention systems is drawn from the Melbourne Water publication *WSUD Engineering Procedures: Stormwater* (June 2004, Chapter 6, p21):

"The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could impact on plant growth particularly in developing catchments with poor building controls.

Maintenance is primarily concerned with:

- *Maintenance of flow to and through the bioretention basin*
- *Maintaining vegetation*
- *Preventing undesired overgrowth vegetation from taking over the bioretention basin*
- *Removal of accumulated sediments*
- *Litter and debris removal*

Vegetation maintenance will include:

- *Fertilising plants*
- *Removal of noxious plants or weeds*
- *Re-establishment of plants that die.*

Sediment accumulation at the inlets needs to be monitored. Depending on the catchment activities (eg building phase) the deposition of sediment can tend to smother plants and reduce the ponding volume available. Should excessive sediment build up it will impact on plant health and require removal before it reduces the infiltration rate of the filter media.

Similar to other types of practices, debris removal is an ongoing maintenance function. Debris, if not remove, can block inlets or outlets, and can be unsightly if located in a visible location. Inspection and removal of debris should be done regularly, but debris should be removed whenever observed on the site."

Given the above, a three monthly inspection frequency is proposed until the catchment has become stabilised (i.e. buildings within the development are largely complete). After this time, the frequency of inspections can be reduced to every six months or as determined by the operational performance of the devices. A more formal monitoring and maintenance program will be produced as part of detailed design.

5. CONCLUSION

Peter Van Lieshout plans to develop an area of land on Kyogle Road in the Kunghur area of north-eastern New South Wales to create a residential village. To ensure that water quality is maintained following development, water sensitive urban design measures have been employed around the site to treat runoff at source.

The proposed development has been divided into three stages, all containing several zones of various development type and density. In order to protect the water quality of the River Tweed, flowing through the south of the site, a treatment train of water sensitive urban drainage measures has been formulated for each.

The techniques employed include rainwater tanks, buffer strips, infiltration systems, vegetated swales, gross pollutant traps and bioretention basins; all of which will be subject to detailed design at a later stage in accordance with the guidance available from Tweed Shire Council (Development Design Specification D7).

The proposed site and its outline treatment systems have been modelled using the industry-standard software, MUSIC 3.01. The modelling has demonstrated that development can proceed without adverse effect on the local environment.

Firstly, concentrations of pollutants discharged from the site are lower than the interim water quality objectives defined by council. Secondly, the total annual load of pollutants following development will be lower than the existing situation. Thirdly, the total pollutant load, when expressed as an annual discharge per hectare, meets or closely approaches permissible limits set by Council. Lastly, the overall efficiency of each treatment train achieves the accepted removal targets.

In order to prevent or exacerbate flooding downstream, the rate of runoff from the site following development has also been addressed. Through a combination of existing and proposed detention basins, and the storage capacity inherent in the proposed bioretention basins, it has been shown that runoff rates following development will resemble those of the existing situation.

FIGURES

Figure One: Schematic Treatment Train (Stage 1)

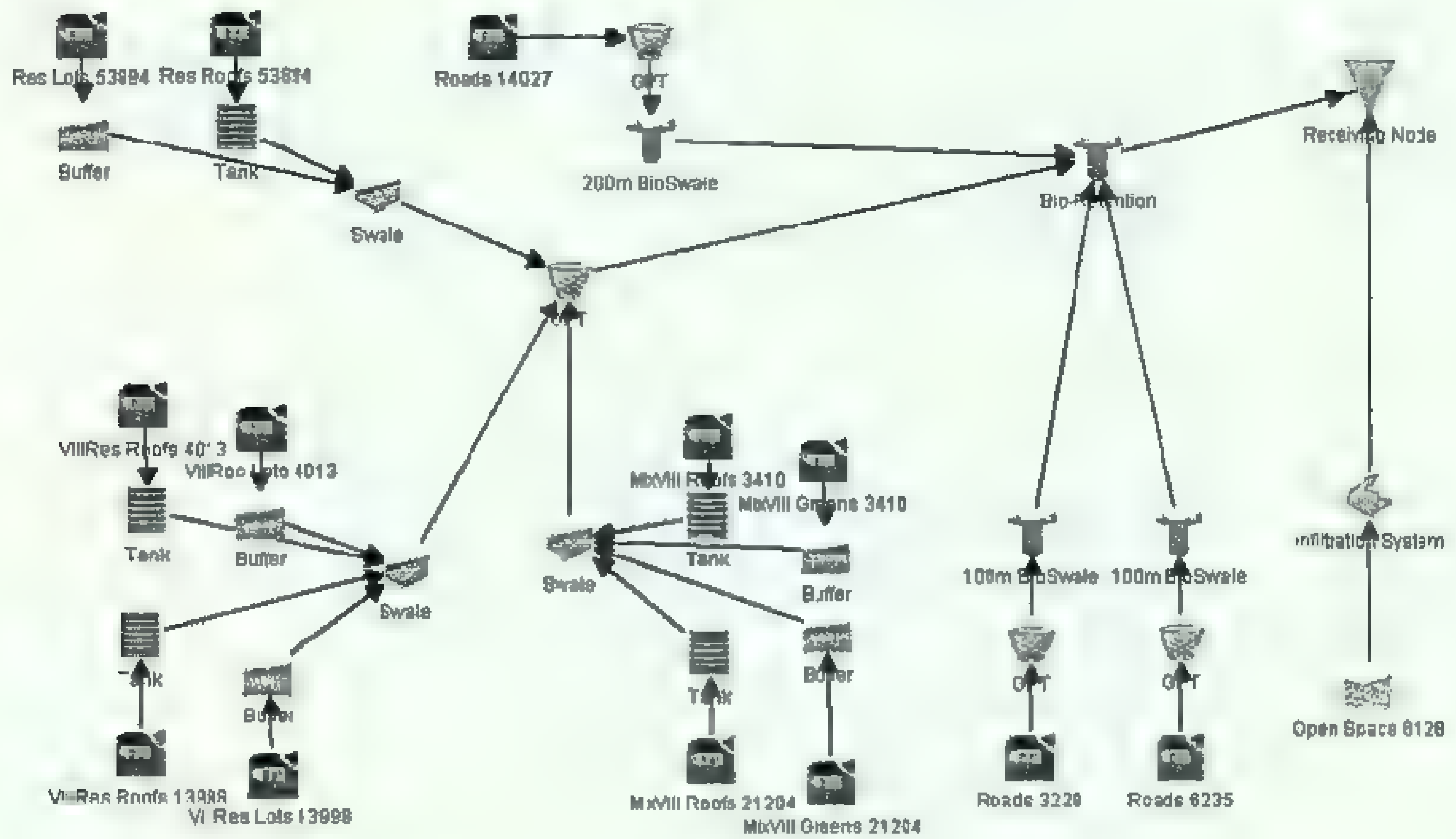


Figure Two: Schematic Treatment Train (Stage 2)

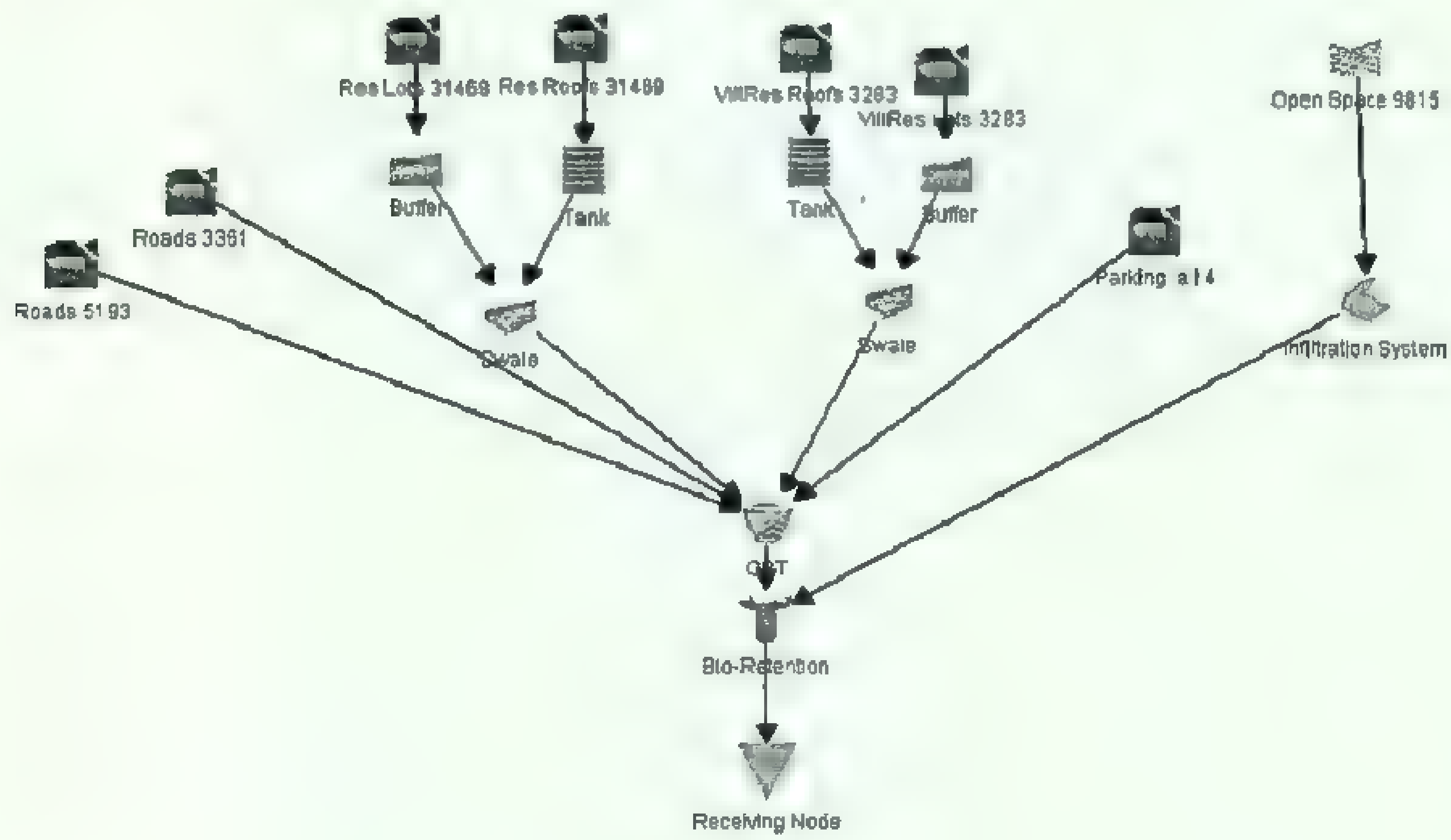
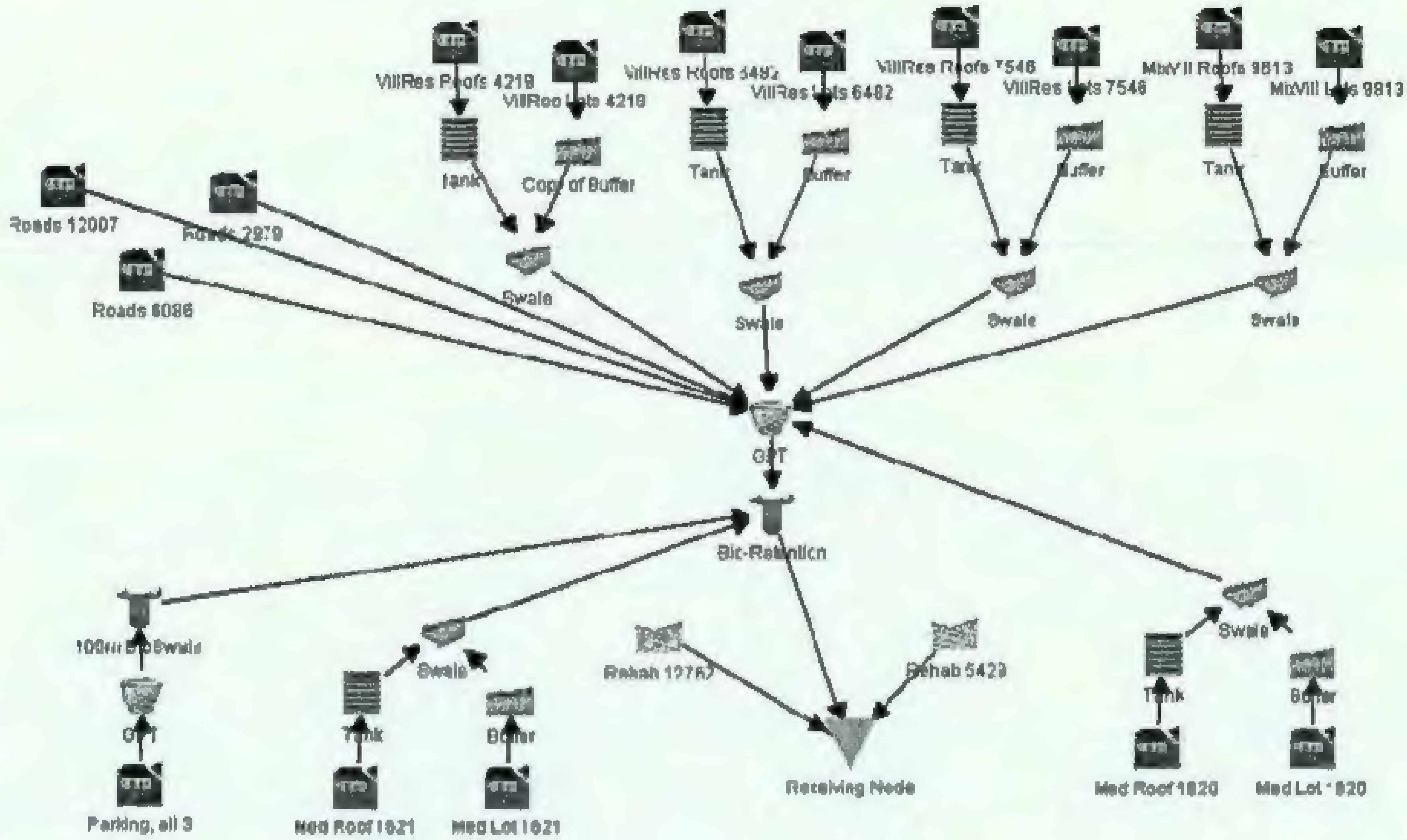
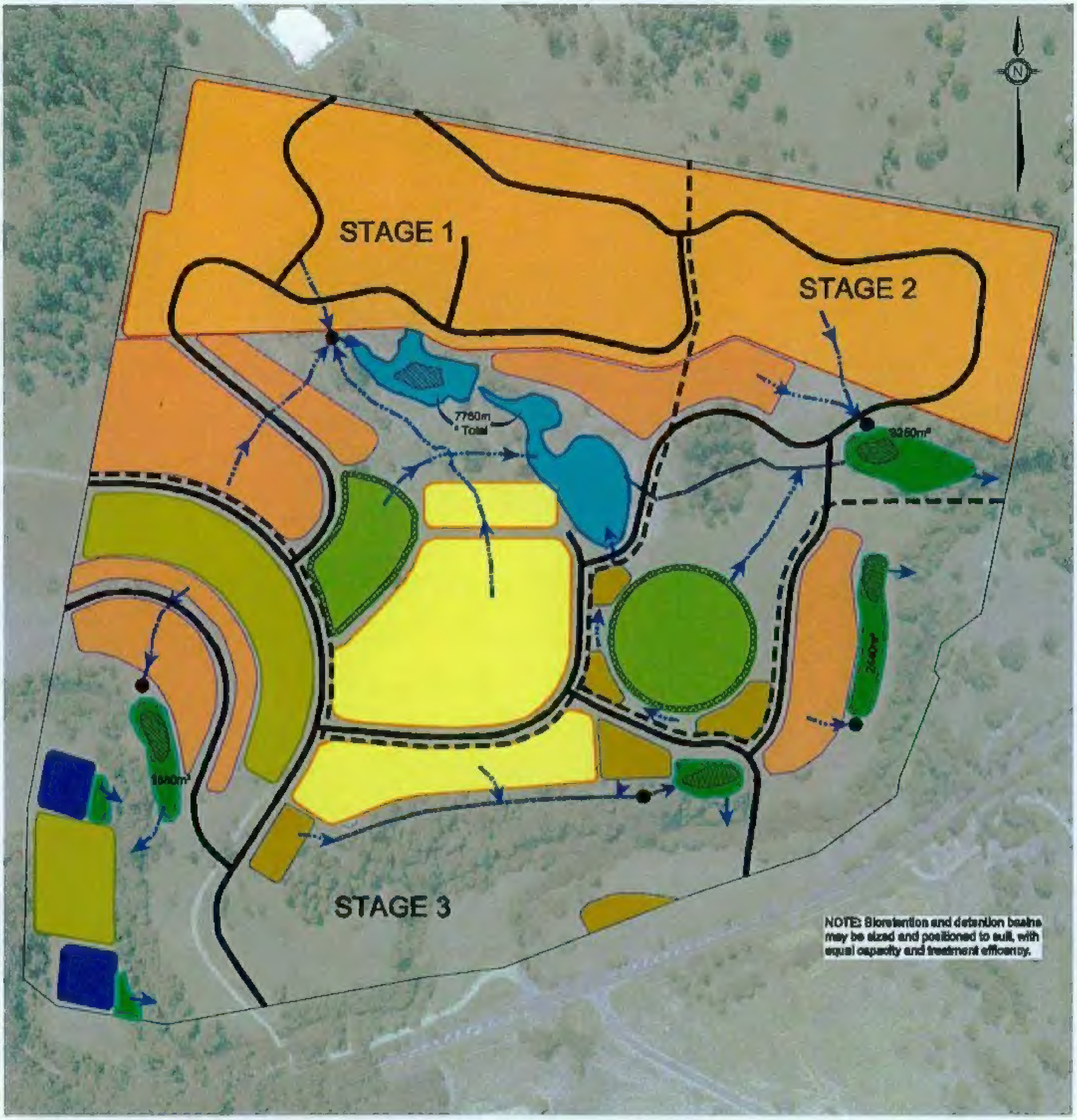


Figure Three: Schematic Treatment Train (Stage 3)





STRUCTURE PLAN

- Residential
- Mixed Village
- Car Parking
- Proposed Treatment Devices
- Open Space
- Tourism/Special Use
- Rehabilitation Areas
- Conveyance Channel/Swale

LEGEND

- GPT
- Infiltration System
- Bioretention Filter
- Staging Boundary

Rev: A Date: 30 June 2008
Peter Van Lieshout

Scale 1:3000 (A3)

FIGURE 4
CONCEPTUAL STORMWATER DRAINAGE SYSTEM

Project No.: 3500/53

APPENDIX A

Music Parameters

Runoff Generation Parameters

Parameter	Urban Tweed	Rural Tweed	Undeveloped Tweed
Field Capacity (mm)	50	50	50
Infiltration Capacity Coefficient a	50	50	50
Infiltration Capacity Exponent b	2	2	2
Rainfall Threshold (mm)	1	1	1
Soil Capacity (mm)	150	150	150
Initial Storage (%)	25	25	25
Daily Recharge Rate (%)	0.65	0.65	0.65
Daily Drainage Rate (%)	.85	0.85	0.85
Initial Depth (mm)	50	50	50

Pollutant Export Relationships

Land Use Source Nodes	Parameter	Total Suspended Solids (mg/L)		Total Phosphorus (mg/L)		Total Nitrogen (mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban Tweed	Mean	0.800	2.000	-1.000	-0.680	-0.100	0.193
	Std Dev.	0.200	0.145	0.340	0.280	0.050	0.050
Rural Tweed	Mean	0.600	1.627	-1.400	-0.950	-0.150	-0.250
	Std Dev.	0.200	0.200	0.400	0.100	0.400	0.197
Undeveloped Tweed	Mean	0.800	1.200	-1.000	-1.470	-0.100	-0.900
	Std Dev.	0.200	0.145	0.340	0.300	0.050	0.100